



# HOW TO USE A DIGITAL MULTIMETER

The Quick Guide to Learn How To Use A Digital Multimeter To Measure Voltage, Current And More Correctly, Diagnose And Fix Anything Electronic

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## INTRODUCTION

If a device suddenly stops working at home or at work, it is more than annoying. It is often also completely unclear whether the fault is with the device or just with the power supply.

How good when you have a multifunctional measuring device at hand and can get to the bottom of the cause of the error in no time. But how is a multimeter properly operated? How are the test leads connected correctly? What do I have to pay attention to when measuring? We explain these questions in this guide and show what is important when measuring with the multimeter.



## CHAPTER 1

### What is a Multimeter?

The term ***meter*** is not just a measure of length. The most diverse measuring devices are also often referred to as ***meters*** .

To make a distinction, the measured variable is simply given at the front. Designations such as tachometer, thermometer, barometer or hygrometer have become established in our daily usage.

Similarly, there are voltmeters for voltage measurement in electronics, ammeters for current measurement or ohmmeters for resistance measurement. If a measuring device covers several functions at the same time, it is called a multimeter.



*This analog built-in voltmeter only shows voltages.*

Table-top multimeters are available for stationary use in workshops and hand-held multimeters are suitable for mobile use.

### **An Analog Multimeter or Digital?**

The first multimeters were analog multimeters and had a pointer instrument to display the measured values.

However, this often led to reading errors. Either you read the value on the wrong scale or looked sideways at the instrument.

In order to avoid at least lateral viewing angle errors (parallax errors), some manufacturers have integrated reflective surfaces into the scales. If the pointer and the mirror image are aligned, you look straight at the scale and can read off the correct value.

With the development of digital technology, multimeters also became digital. Instead of a deflecting pointer, the measured value is now digitally displayed in large digits.

This means that the mechanically susceptible pointer instrument has finally had its day. The new devices are known as digital multimeters or DMMs.



*At the end of the 1970s, the dream of every TV technician apprentice.*

## **CHAPTER 2**

### **What Can Be Measured with a Multimeter?**

A wide variety of electrical parameters can be recorded with an inexpensive digital multimeter. But before you start measuring, you have to be clear about which measured value is to be recorded. Since beginners in measurement technology, in particular, tend to confuse current and voltage, we will explain the most important measured variables in more detail.

### **Voltage**

The electrical voltage is, as it were, the drive for the electrical current. Since the electric current is an exchange of charge carriers (electrons), there is an excess of electrons (-) at one pole and a shortage of electrons (+) at the other pole. Depending how greater the difference is between excess or deficiency, the higher is the voltage. In simple terms, one can say that the voltage describes the force or strength of a voltage source.

The symbol for the voltage is  $U$  and the unit is 1 volt (V) .

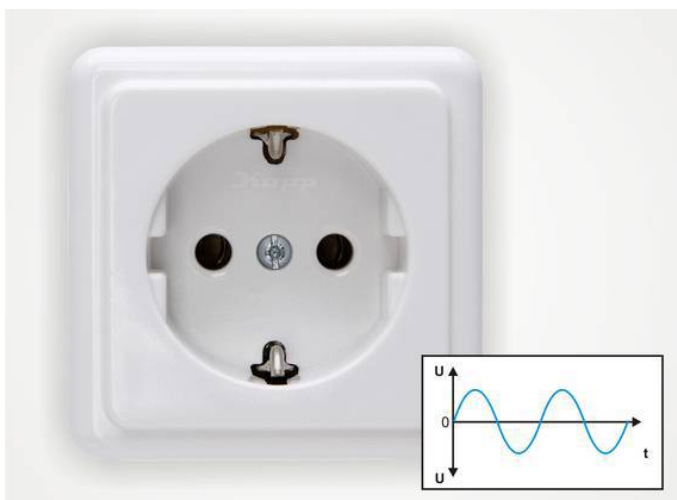
### **DC Voltage**



*Batteries are typical DC voltage sources*

If the level of the voltage does not change over a certain period of time, it is referred to as direct voltage  $V$  / DC (DC = Direct Current). Typical voltage sources with direct voltage are batteries, accumulators or power packs.

## AC Voltage



*Sockets emit an alternating voltage.*

If the level of the voltage changes periodically and the mean values of the positive and negative components are the same, in that case, we speak of alternating voltage V/AC (AC = Alternating Current). Typical voltage sources for AC voltage are mains sockets or mains transformers.

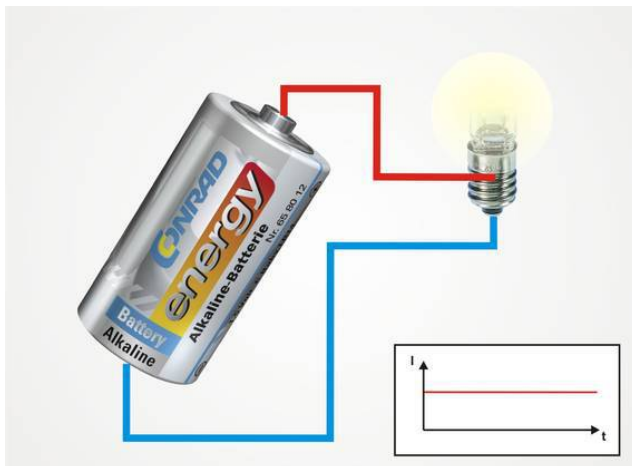
## Electric Current

When the two poles of a voltage source are conductively connected to one another via a consumer, an electric current flows. This means that on the side of the voltage source with the excess of electrons, the electrons are fed into the circuit. On the side of the voltage source with the electron shortage, electrons are withdrawn from the circuit.

In principle, the voltage source tries to compensate for the excess/deficiency situation via the circuit. The current level depends on the level of the voltage at the voltage source and the consumer's resistance.

The symbol for the current is  $I$  and the unit is 1 ampere (A) .

## Direct Current

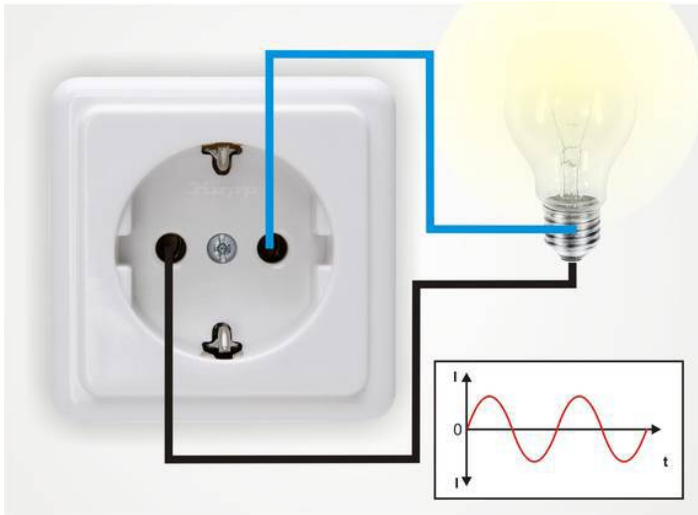


*Simple circuit with a battery as a voltage source.*

When the voltage source supplies a direct voltage, the current flows continuously in one direction. In this case, it is direct current (A/

DC).

## Alternating Current



*Simple circuit with a socket as a voltage source.*

With an AC voltage source, the current changes direction, just like the voltage. In this case, one speaks of alternating current (A / AC).

Depending on the equipment, digital multimeters offer additional measurement options.

## Resistance



Even in the lowest price category, many digital multimeters offer the possibility of measuring continuity and resistance.

On the one hand, lines, switches or fuses can be checked without any problems. On the other hand, the exact values of resistances can also be measured.

The symbol for the resistance is **R** and the unit is 1 Ohm ( $\Omega$ ) .

## Capacitance



The capacitance measurement of capacitors works in a similar way to that of resistors. But instead of the DC voltage for resistance measurement, the digital multimeter now generates an AC voltage. As a result, the capacitor to be tested is constantly charged and discharged with alternating polarity. Due to the charging current flowing in the process, the measuring device can determine and display the capacitance of the capacitor. The symbol for the electrical capacitance is **C** and the unit is 1 farad (**F**) .

## Diodes



With the help of the diode test function, the PN junctions of diodes can be checked. This means that the digital multimeter is used to check whether the respective semiconductor lets the current through in one direction and reliably blocks it in the other direction.

With the help of the diode test function, however, transistors can also be tested in the same way. This is because transistors each have a diode path between base (B) and emitter (E) and between base (B) and collector (C).

## **Temperature**



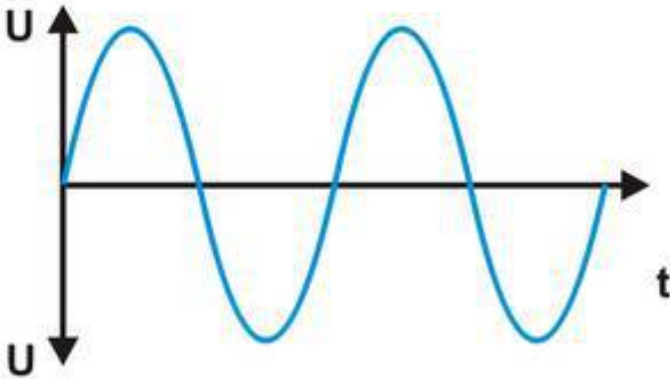
Temperature measurement with a digital multimeter is usually

possible with a sensor specially designed for the measuring device.

These sensors are mostly nickel-chromium-nickel sensors (NiCrNi sensors) type K, which emit a voltage depending on the temperature.

The measuring device records this temperature sensor voltage and the voltage value is assigned to a temperature.

### Frequency



When measuring frequency, the measuring device determines how often a signal oscillates around an average value per second. A positive and a negative value must always result in an oscillation. In the case of a mains frequency of 50 Hz, this results in 50 positive half-waves and 50 negative half-waves. The voltage changes polarity 100 times per second.

## **CHAPTER 3**

### **How is a Multimeter Used Correctly?**

The digital measuring device must be correctly set and connected so that voltage, current or other electrical parameters can be measured precisely.

Various control elements and connections are available for this purpose, which we would like to demonstrate using a VOLTcraft multimeter of the VC 100 series as an example.

### **Control Elements of a Multimeter**



### 1. Display

The display not only shows the measurement result. Other information such as the measuring range, auto-ranging and the voltage level of the internal battery is often displayed.

### 2. Rotary Switch for Manual Measuring Range Selection

The rotary switch is used to set the measuring range manually. Since the multimeter has an auto-range function, there is only one switch position for both DC and AC voltage. The measuring device determines the voltage measuring range or the comma in the display based on the measured values.

In contrast to this, when measuring the current, the user has to choose whether the measured current is in the  $\mu\text{A}$  range, in the  $\text{mA}$  range or in the ampere range.

### 3. Test

Socket (-): The black test lead is connected to this socket. It serves

as a common ground potential (COM) for voltage and current measurements.

#### **4. Measuring**

Socket (+): The red measuring probe or line is connected to this socket. With the exception of current measurement from 0.2 to 10 A, this socket serves as a common plus potential for voltage and current measurements.

5. Measuring socket 10 A, for a current measurement of 0.2 to 10 amperes, this socket must be used as a positive connection for the measuring lines.

#### **6. Function**

Switches: These switches can be used to activate various measuring and special functions.

#### **7. Test Leads**

The test leads connect the measuring device to the measuring object.

### **Connect the Test Leads to the Multimeter**

If voltages and low currents are to be measured or components are to be checked, the red measuring line must be plugged into the measuring socket (4). The black measuring line must be connected to the middle measuring socket (3).

As a rule, the measuring device sockets are clearly labeled so that incorrect connection of the measuring lines does not occur. In case of doubt, the enclosed operating instructions will help.

### **Select the Correct Measuring Range**



*Choosing the right measuring range is extremely important.*

Before the measurement can be started, the required measuring range (e.g. voltage, current or resistance) must be selected with the rotary switch. This is very important and must be done conscientiously. Because depending on which measuring range has been set, the measuring device behaves differently.

If the digital multimeter has been set to measure voltage, the measuring device is high-resistance. This implies that the internal resistance of the measuring device is very high.

If the digital multimeter was set to measure current, the measuring device is low-resistance. This means that the internal resistance of the measuring device is very small.

**Note :** If for example, a voltage measurement is planned and the measuring device has been set to a current measuring range by mistake, the measuring device behaves like a wire bridge and thus represents a short circuit! The measuring circuit and the measuring device can be destroyed!

**Practical Tip :** Many multimeters are equipped with fuses that trigger when the currents are too high due to incorrect operation. If an error occurs, the entire measuring device may not have to be disposed of, but only the fuse is replaced. In some cases, manufacturers even include replacement fuses with their devices.

## Switch on the Multimeter

Many multimeters switch on automatically when the rotary switch is turned from the **OFF** position to the required measuring range. After the measurement, the rotary switch must be returned to the **OFF** position. Other multimeters have an additional **On/Off** switch with which the device is put into operation.

To save the internal battery, most multimeters switch off automatically after a period of time without operation.

If the test leads have been connected correctly and the correct measuring range has been set, the multimeter is ready for measurement.

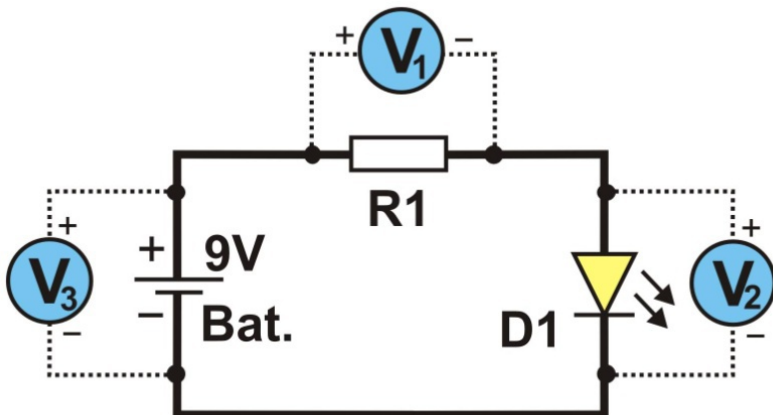
## CHAPTER 4

### How is Voltage Measured with a Multimeter?

Voltage measurement is one of the simplest measurements available in electronics or electrical engineering because the multimeter is simply switched in parallel to the voltage source or the object to be measured.

In order to prevent excessive current from flowing through the measuring device and thus falsifying the measurement result, it has a very high internal resistance when measuring the voltage.

The illustration below shows a simple circuit with a 9V battery, a series resistor for voltage reduction (R1) and a LED (D1).



### *Circuit with different possibilities to measure voltages*

If the voltage is to be measured across the resistor, the digital multimeter must work as a voltmeter (V) and be connected accordingly to V1. If the voltage is to be measured via the LED, the digital multimeter must be connected according to V2.

Both voltages together must result in the battery voltage. To measure this, the multimeter must be connected in accordance with V3.

### **Measure Correctly**

The polarity of the measuring lines is important when measuring voltage. If the measuring tips are placed the wrong way round on the measuring points, the pointer of an analog measuring device will deflect to the left. With a digital multimeter, a negative measured value (e.g., -5.62 V) would be displayed.

### **Test the Battery with a Multimeter**



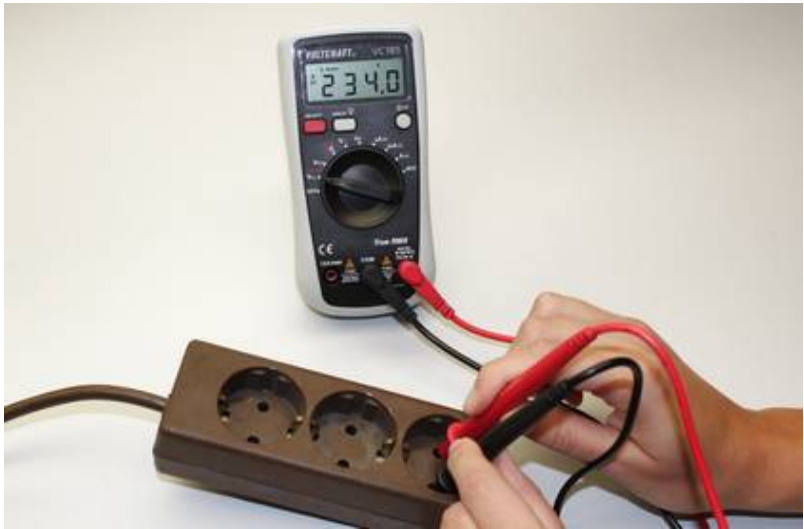
The voltage measurement on a battery is often practiced but is not necessarily very meaningful, because the high-resistance measuring device does not load the battery sufficiently.

It may well happen that the full voltage is displayed during the

measurement but the battery breaks down after a short period of use.

If the multimeter shows a voltage value that is far too low when measuring without load, the battery can be disposed of immediately.

## Check the Mains Voltage with the Multimeter

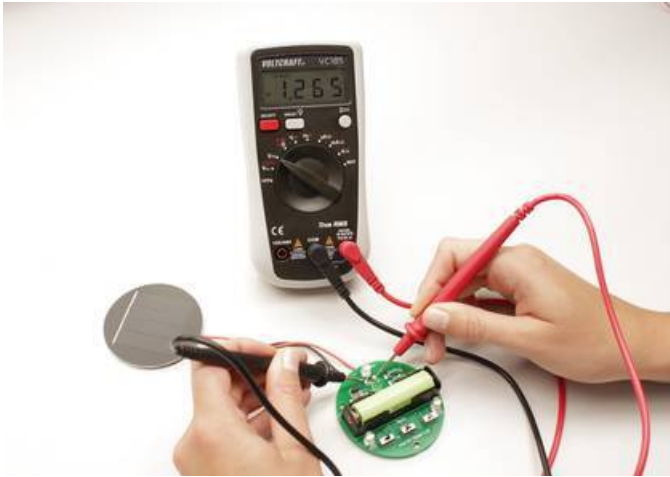


When renovating, it is often inevitable that lamps or sockets have to be dismantled or moved. It is of vital importance to check whether there is voltage on the lines and connections before loosening the clamp connections. Suitable multimeters do a good job here. However, the user must know exactly what to do.

Measurements in circuits **>33V/AC and > 70V/DC** may only be carried out by specialists and trained persons who are familiar with the relevant regulations and the resulting dangers.

**Note :** When it is 230V power, it is an AC voltage. The multimeter must therefore be set to AC voltage. If it is on DC voltage, it will show 0V or only a low value of a few volts, even if the full mains voltage is present. A measurement error that can have fatal consequences.

## Voltage Measurements in Electronics



Voltage measurements in electronics are also easy to carry out because the measuring tips only have to be placed on the soldering eyes or on the connecting legs of the components.

However, some electronic know-how is required to assess the measurement results and to find the fault in the circuit.

LED solar lights are ideal for getting started with measurement technology because the circuit structure is manageable and with a little practice, it quickly becomes clear why the expensive stainless steel lamp no longer works.

## **Check the Lambda Probe with the Multimeter**



Experienced car mechanics also like to use a digital multimeter when they have electronic problems. Specialists even manage to use it to test the functionality of the lambda probe, especially when there is no OBD diagnostic device available to read out error codes.

However, you have to know exactly which cables the probe voltage is used on and which connections the probe uses for heating.

Even if a digital multimeter is basically much too slow to display the rapid voltage jumps of the probe precisely, you can see at least in the range of 0.2 to 0.8 V whether the probe shows a control behavior.

## CHAPTER 5

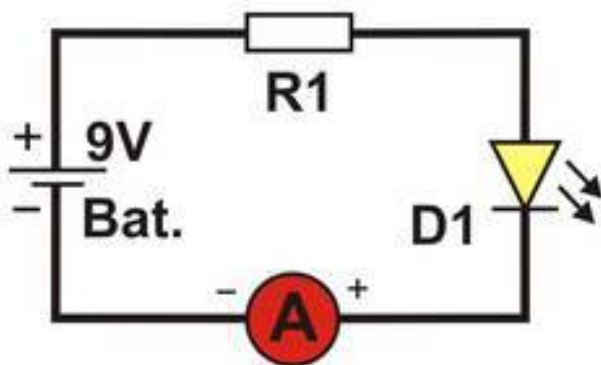
### How is Current Measured with a Multimeter?

The current measurement with a multimeter is a bit more complex because now the circuit has to be separated at any point and the measuring device switched into the circuit. This is the only way to measure the current actually flowing.

The measuring device has a very low internal resistance so that it does not show any additional resistance in the circuit. It can be seen as a **wire bridge** .

As with voltage measurement, it is important to ensure that the polarity of the measuring lines is correct when measuring current. If the polarity is incorrect, a negative measured value is shown on the display.

The illustration below shows a simple circuit with a 9V battery, a series resistor (R1) and an LED (D1).



*Simple circuit with ammeter for current measurement*

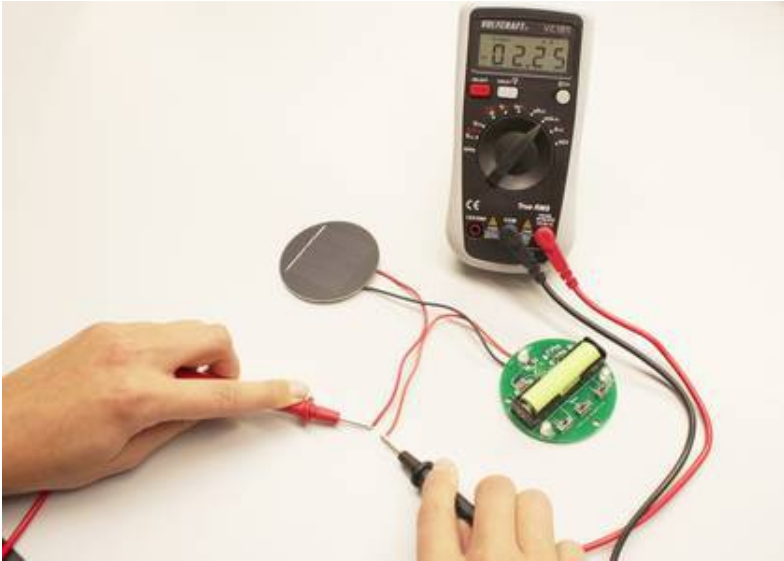
If the current is to be measured within this circuit, the digital multimeter must act as an ammeter (A). It is absolutely irrelevant where the circuit is cut and the ammeter is connected in between because the current is the same at every point in a circuit.

**Practical Tip :** If it is not clear how high the current to be measured will be (within the permissible limits of the measuring device), you must always start in the largest measuring range. If necessary, you can switch to a smaller measuring range in order to be able to carry out more precise measurements.

**Note :** During service and repair, the current measurement is rarely carried out because it is not as helpful for troubleshooting as the voltage measurement. After all, a voltage must first be present so that a current can flow. But there are some areas where current measurement is still important.

## **Check the Solar Module with the Multimeter**

With solar modules, there are two important parameters that can be checked with a multimeter. The first value is the open-circuit voltage that the solar module generates when the sun shines on the module with full force at a 90 ° angle. Only the high-resistance voltage measuring device may be connected to the solar module for correct measurement.



The second important value is the short circuit current. In contrast to rechargeable batteries, a solar module can be short-circuited without hesitation. The current flowing, as well as the open-circuit voltage is specified in the technical data. Since both values can be measured with a multimeter without any problems, the performance of a solar module can be tested quickly and easily. The charging current can also be measured during operation.

### **Current Clamp for Multimeter**

If particularly high currents flow in the automotive sector or in electric model airplanes, how is the current measurement difficult?

Because you can't just cut the circuit and switch the measuring device in between. For this reason, current clamps were developed years ago.



Every conductor through which current flows generates a magnetic field. The strength of the magnetic field depends on the level of the current.

A current clamp surrounds the conductor and can generate a voltage based on the magnetic field. This voltage is measured by the multimeter and assigned to a current value, which is then shown on the display.

As ingeniously simple as this method is, it unfortunately only works with individual ladders. Unfortunately, a current clamp does not work with a mains extension cable with several current-carrying conductors within a sheath.



Due to the different current directions within the cable, the magnetic fields cancel each other out.

For this case, however, there are special measuring adapters in which each current-carrying line can be individually encompassed by the clamp ammeter.

### **Measuring Temperature with a Multimeter**

As already mentioned, a suitable sensor for the measuring device is required for temperature measurement. These sensors are either enclosed with the multimeter or offered as an option.



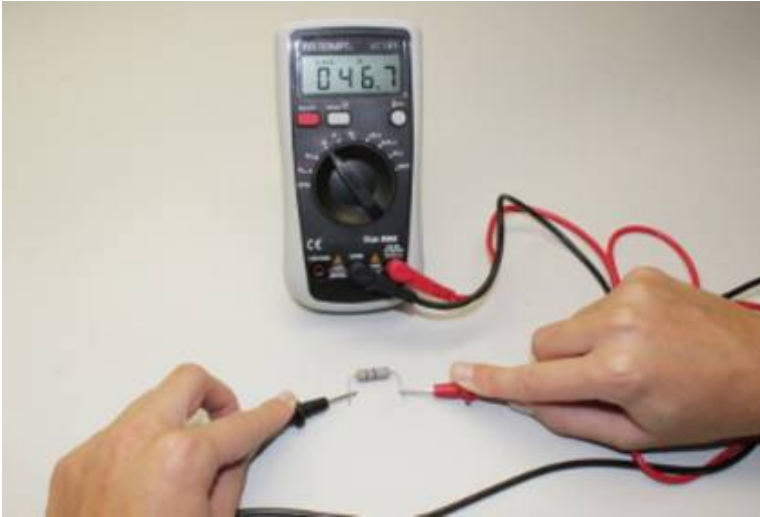
*Temperatures can easily be measured with the right probe*

Depending on the version of the multimeter, the temperature sensor is connected to separately designated flat plug sockets instead of the measuring lines or in the case of older devices, the multimeter assigns the determined sensor values to a temperature and shows this on the display.

## **How Are Components Checked with a Multimeter?**

In addition to voltage and current measurement, many multimeters also offer the option of testing components. It is important that the components must be checked when they have been removed and de-energized. Capacitors may have a residual charge that must be discharged before the measurement.

## **Measure Resistance with a Multimeter**



*The measured value can be assessed using the color coding*

When measuring resistance, the battery of the multimeter serves as a voltage source. This means that when measuring resistance, there is a low DC voltage at the measuring tips of the multimeter when the rotary switch is switched to the **Ohm** measuring range.

If the two measuring tips are connected to the two connections of the resistor, a small measuring current flows.

Depending on how high the current is, the multimeter determines a resistance value and displays it together with the measuring range ( $\Omega$ ,  $k\Omega$  or  $M\Omega$ ).

### **Multimeter As a Continuity Tester**

In addition to resistance measurement, some multimeters also offer the continuity function. With this function, low-resistance components such as fuses, switches or even conductor tracks can be tested quickly and easily. The electrically conductive passage is also indicated acoustically so that you can concentrate on the measurement object. So you don't have to read the resistance value on the display.

### **Measure the Insulation Resistance with a Multimeter**

The measurement of the insulation resistance is required by law for electrical systems and equipment as well as for electric vehicles.

This means that defects that affect the functionality and safety can be identified and eliminated in advance.

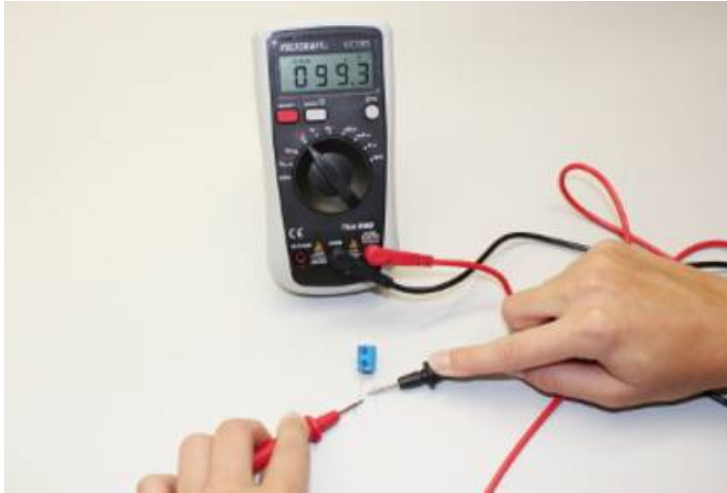


*Looks like a multimeter, but it's an insulation meter*

Since a standard multimeter cannot generate the required measuring voltage of up to 1000V/DC, special insulation measuring devices are required for insulation measurement.

### **Check the Capacitor with a Multimeter**

The capacitance measurement is carried out according to the same scheme as the resistance measurement. This means that the capacitor to be measured is connected to the two measuring lines.



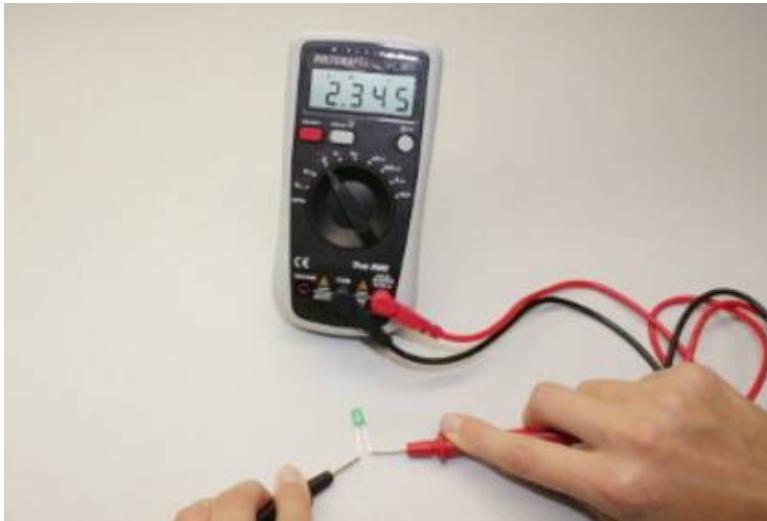
*The measured value should correspond to the printed value*

When measuring capacitance, the multimeter must output an alternating voltage instead of direct voltage for resistance measurement. This is the only way to continuously charge the capacitor alternately.

The current that flows when the capacitor is constantly reversed depends on the capacitance of the capacitor. This charging current is measured by the multimeter and assigned to a capacity value, which is then displayed.

### **Check Diodes with a Multimeter**

As with resistance measurement, the multimeter outputs a voltage on the measuring lines during the diode test. If the voltage at the measuring tips is polarized so that the diode blocks and does not allow current to flow, no voltage is shown in the display.



*Intact light-emitting diodes can start to glow during the test*

If the voltage at the measuring tips is polarized so that the diode allows a current to flow, the forward voltage of the diode is shown in the display appears.

Intact standard diode, the voltage in the forward direction is about 0.6 to 0.7 V and Schottky diodes approximately 0.4V. In light emitting diodes, the forward voltage and the type of color is dependent and can on average, by 1.6 - 3.7 V, respectively.

In some cases, the measurement current in the forward direction is sufficient to make the light-emitting diodes glow.

**Note :** With some digital multimeters, the resistance value is displayed instead of the forward voltage. In the reverse direction, the resistance is infinite and in the forward direction the resistance is between 400 and 800 ohms, depending on the type of diode.

## **Technical Terms Used with Multimeter As Measuring Device**

Often you can find terms in the descriptions of digital multimeters that are not clearly explained. That is why I want to explain the most important technical terms in more detail.

### **Auto Range**

Multimeters with auto range function use the measured value to identify the range that must be displayed. When measuring resistance, not only the measured value of e.g., 10.8 but also the measuring range  $\Omega$ ,  $k\Omega$  or  $M\Omega$  is displayed.

Multimeters without auto ranging, each have their own switch positions for the different measuring ranges.

## **True RMS**

The abbreviation RMS stands for Root Mean Square and means something like root mean square or effective value. A TRMS multimeter is therefore, able to display the real rms value.

This is important in the case of asymmetrical alternating voltages or alternating currents that do not correspond to the basic shape of a sine. Such voltages are generated, for example, by dimmers, clocked switching regulators or pulsed charging devices. Conventional mean value measuring devices can sometimes show large deviations in the measurement results for these special measuring tasks.

## **Counts**

The counts specification defines the display resolution. A multimeter with 2000 counts can display a number range from 0 - 1999. With 4000 counts, the display range is 0 - 3999. The position of the comma is determined automatically by the measuring device. A measuring device with 2000 counts can therefore display voltages up to 199.9 V with one decimal place. If a higher voltage (e.g., 230.6 V) is measured, the decimal place is omitted and 230 V is displayed. A measuring device with 4000 counts (0 - 3999) can correctly display the measured value of 230.6 V.

The resolution of the measured value results from the number of counts. In the measuring range of 20V, 2000 counts have a resolution of 10 mV (20 V: 2000 = 0.01 V). With 4000 counts, the resolution would be 0.005 V or 5 mV.

## **CAT**

The abbreviation CAT describes the measurement category for which the measuring device is designed. The following categories are defined according to EN 61010-1:

**CAT I** : For measurements on battery-operated circuits that have no

direct connection to the power grid. Examples: flashlights, remote controls or vehicle electrics.

**CAT II** : For measurements on circuits that have a direct connection to the mains via a mains plug. Examples: household appliances or power tools.

**CAT III** : For measurements within the building installation where the consumers are permanently wired to the power grid. Examples: sub-distributors, sockets or lamps.

**CAT IV** : For measurements at the source of the low-voltage installation. Examples: electricity meters, main connection, main fuses, photovoltaic systems or vehicles with electric drives.

## **Calibration**

Users who have to document their measurement results traceably due to applicable regulations use measuring devices calibrated according to DIN or ISO. During calibration, it is verifiably documented that the measuring device works within the permissible tolerances. The calibration does not intervene or change the measuring device. The calibration must be repeated at regular intervals.

## **Duty Cycle**

With a square wave signal, the degree of utilization or duty cycle indicates the ratio of the positive pulse (switch-on pulse) to the period duration. At a frequency of 50 Hz, the period is 20 ms. If the positive pulse is 1 ms wide, the duty cycle is 5%.

## **Conclusion**

A small digital handheld multimeter is found in every home. The multifunctional measuring aids are perfect for finding electrical faults in systems, vehicles or devices. But not only that, even in the lowest price range, you can now get high-quality measurement device with many ingenious additional functions. And once the first voltage measurements have been successfully completed, you will quickly discover other possible uses for your measuring device.

Irrespective of the electrical fault you want to discover in your electronic appliances, you will need to familiarize yourself with the basics of the multimeter before you begin. Are you ready to start troubleshooting and measuring faulty electronic devices at home? Go on, familiarize yourself with this book and get started.